AD-A129 491 DESIGN PLAN FOR 0 DBI VHF-FM AIRCRAFT COMMUNICATIONS ANTENNA SYSTEM(U) HAZELTINE CORP GREENLAWN NY E M NEWMAN 31 OCT 79 DAAK80-79-C-0279 1/1

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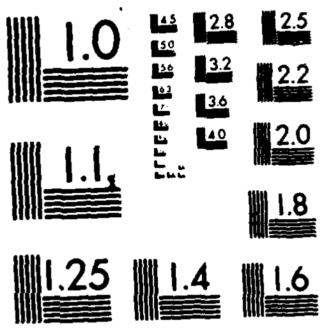

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Hazeltine

DESIGN PLAN

FOR 0 dBi VHF-FM

AIRCRAFT COMMUNICATIONS

ANTENNA SYSTEM

Contract DAAK-80-79-C-0279

2

Hazeltine
Corporation
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DESIGN PLAN
FOR 0 dBi VHF-FM
AIRCRAFT COMMUNICATIONS
ANTENNA SYSTEM

Contract DAAK-80-79-C-0279

31 October 1979

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Hazeltine and the Pursuit of Excellence

Hazeltine Corporation

1.0 INTRODUCTION

This design plan, submitted in accordance with the requirements of contract DAAK80-79-C-0279, describes the design of a zero dBi aircraft antenna for operation in the VHF-FM band of 30 to 88 MHz.

The plan is divided into six sections:

1. Introduction
2. Location/Installation
3. Element Design
4. Matching Network
5. Mechanical Configuration
6. Program Plan

The second section discusses two alternative antenna locations as well as the details of the installation of the electronically tuned antenna.

Section three describes the baseline radiating element, the reasons for its selection, and preliminary impedance measurements obtained from a full scale breadboard.

Section four describes the detailed design of the matching network including the overall circuit configuration, high-Q component design, diode selection and logic design.

The information from sections two, three and four is then used in section five to show the detailed mechanical packaging of the 0 dBi antenna. A layout and a detailed weight estimate are included.

Finally, section six presents a detailed outline of the remaining design tasks.

2.0 LOCATION/INSTALLATION

The location of the antenna on the helicopter influences the pattern, vswr, and physical configuration of the antenna element.

A monopole antenna, by itself, has an inherently omnidirectional pattern. The airframe affects the pattern by scattering the radiation from the antenna. The strongest scatterers on the airframe are metal structures which are resonant at the operating frequency. The tail rotor of the OH-58A for example, is resonant at about 86 MHz. Another effect is shadowing by the aircraft. The fuselage blocks radiation in its "shadow", although significant energy diffracts around.

Figure 2-1 shows some alternative locations for a vhf-fm antenna on the OH-58A. Most of these locations have been analyzed by McDonnell Douglas Research Laboratories (1). Their results, one example of which is shown in figure 2-2, are useful for comparing antenna locations. Their neglect of rotor effects, however, means that their data could be in error by several dB.

It is desirable to achieve a near-omnidirectional antenna pattern near the horizon in order to achieve uniform coverage. It appears that a horizontal pattern with ripples of 5 to 7 dB are achieved by monopoles on the helicopter. The highest gain in elevation should be near the horizon, to maximize range during NOE operation. Finally, the polarization should be nominally vertical, although a weak horizontally polarized component may enhance communication reliability by filling in nulls in the vertically polarized coverage. A strong horizontally polarized component will detract from the vertically polarized gain.

The impedance of the antenna element is also affected by the location on the airframe. The helicopter is small enough in wavelengths so that it does not appear as an infinite flat ground plane. At 30 MHz, the OH-58A is approximately 1 wavelength long. An antenna mounted at the end of the tail boom will see an even smaller ground plane.

The airframe effect does not present any serious design problems; however, the antenna impedance will be checked with the antenna mounted on a mockup of a part of the airframe.

Two antenna locations are of special interest. The first is location "A" shown in figure 2-1 -- the present location for the bent whip vhf-fm antenna. As shown in figure 2-3, the antenna has good omnality (4 dB) and almost uniform elevation coverage from -15° to $+15^{\circ}$ relative to the horizon. Measured azimuth patterns agree qualitatively with the calculated patterns.

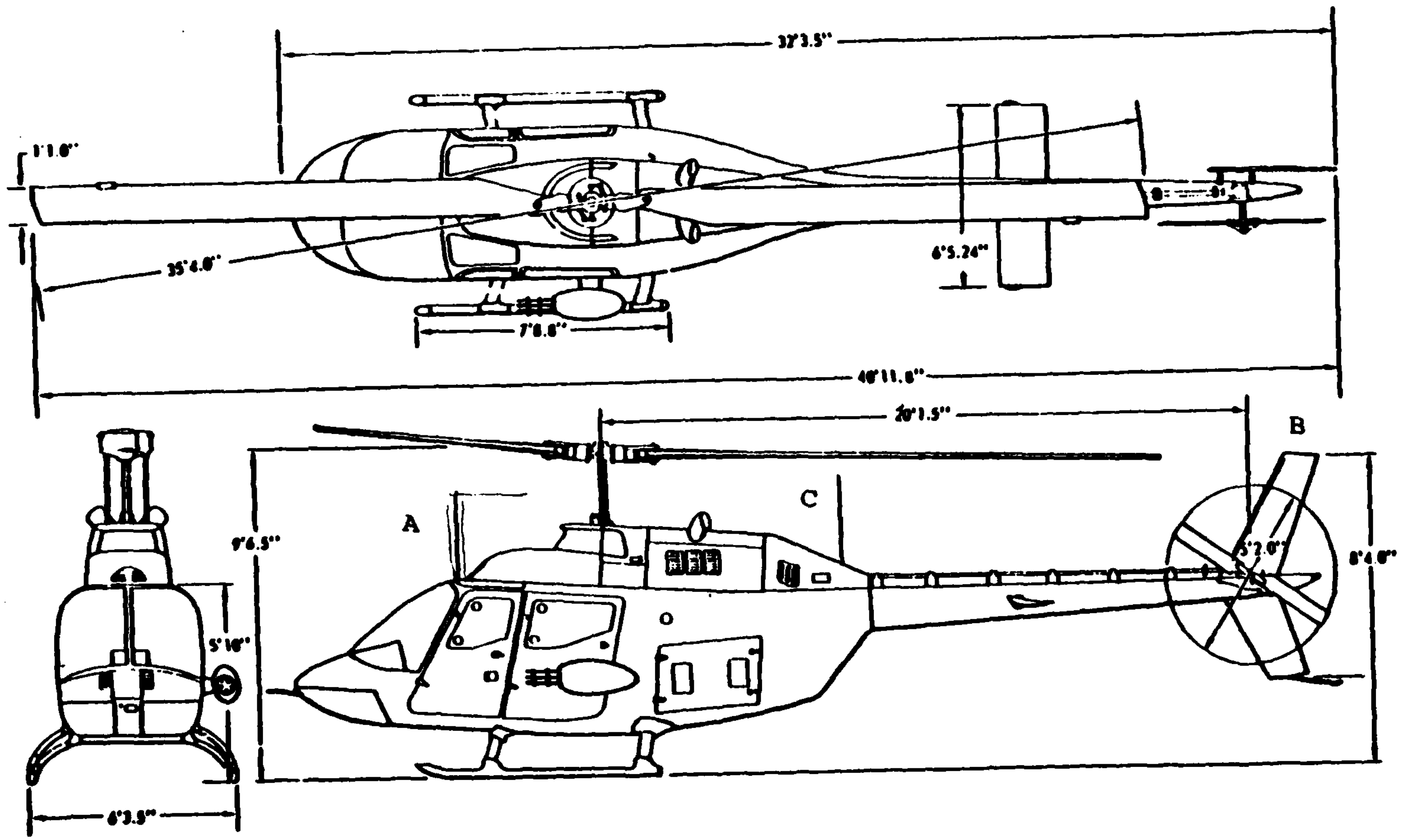

Figure 2-1. Alternative Antenna Locations on OH-58A

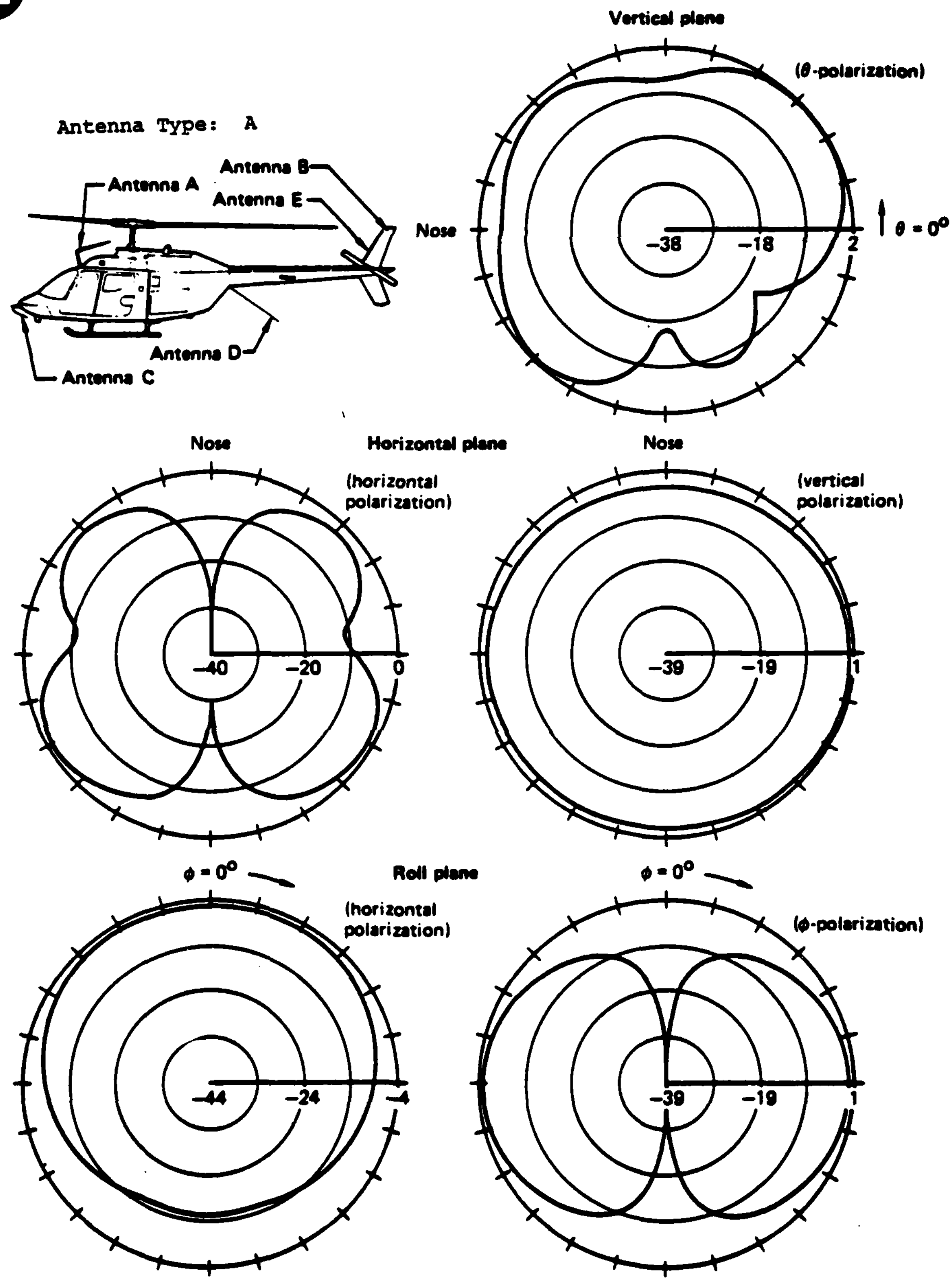

Figure 2-2. Computed Power Gain Patterns in Free Space for OH-58A at 30 MHz (from ref [1])

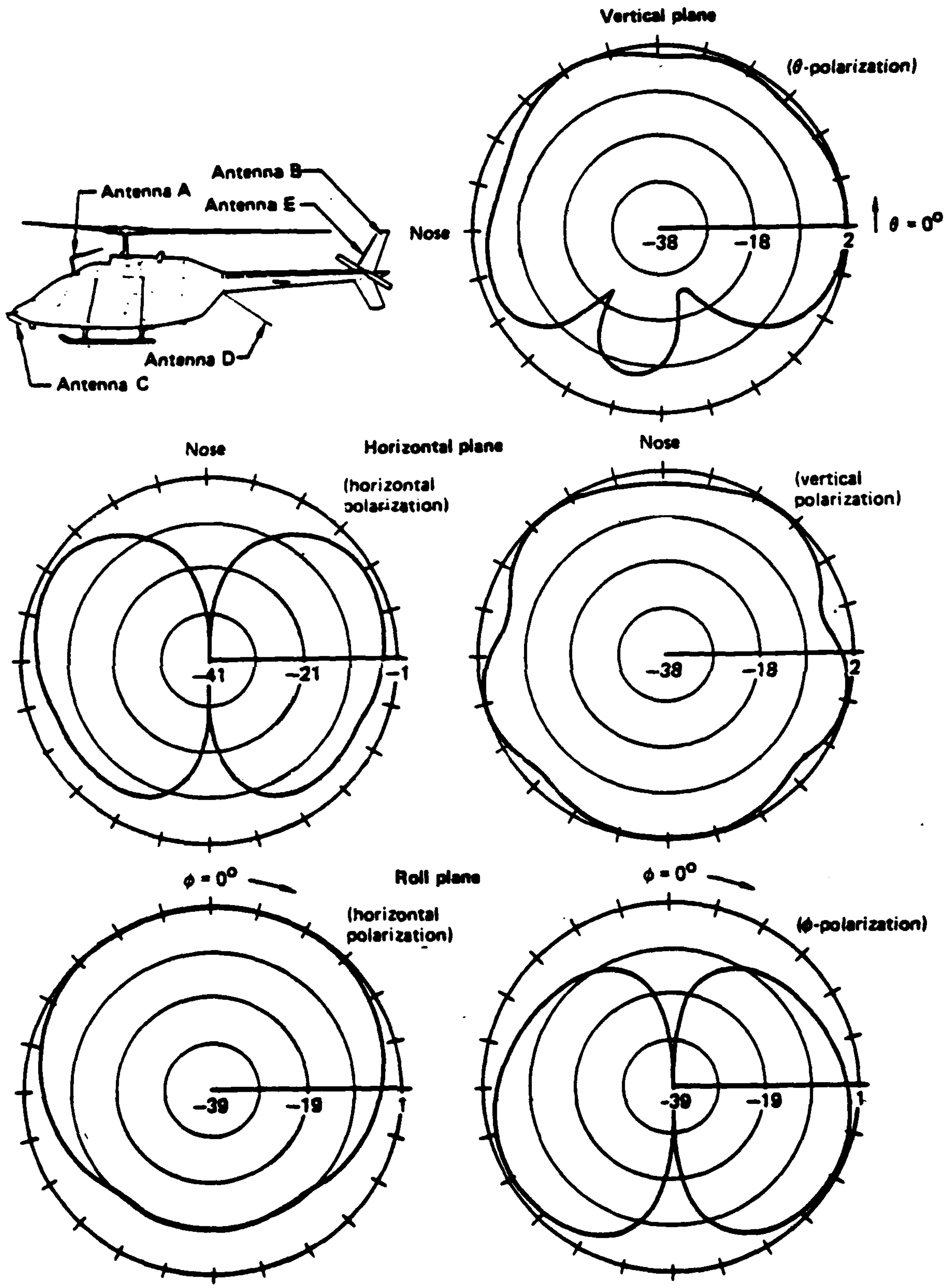

Figure 2-3. Computed Power Gain Patterns in Free Space for OH-58A at 61.65 MHz, Antenna Type A (from ref [1])

This location also has a relatively large, flat area to act as ground plane. However, the proximity of the windows will change the antenna impedance. The proximity of the antenna to be to the rotor blades is also a problem. We expect that the rotor will modulate the pattern of the element. This may not be a serious problem for FM communications because the rotor frequency is low (4 to 20 Hz), and the amplitude modulation is removed during the FM detection process. Finally, the location allows short, low-loss cable runs from the transmitter to the antenna.

A second location to be considered is shown as "C" in figure 2-1. Calculated patterns are not available for this location. However, based on the patterns of configuration D (Ref (1)) as shown in figure 2-4, the antenna should have good omnality. The location at the center of the aircraft provides a good ground plane for the radiator. Also, the cable run to the antenna is approximately half that of the tailfin-mounted antenna.

The UH-1 helicopter, shown in figure 2-5, has an antenna mounting location on top of the cabin, as shown. An evaluation of the radiating element impedance must be made on a mockup to verify that the impedance remains approximately the same. The location of the element on the airframe must be selected based on the estimated pattern performance and element impedance.

A wood or metal mockup of representing the forward section of the OH-58 or UH-1 will be fabricated for making full-scale element impedance measurements.

The electrical interface between the antenna and the helicopter is shown in figure 2-6. The VHF RF signal is brought to the antenna by the existing coaxial cable. The power and control signals are brough via a multiconductor cable and a small interface box.

The antenna requires 12 to 24 volts, two frequency control signal wires and -80 volts. The interface box combines 24 volts from the aircraft power system, the frequency control signals from the ARC-114A and an internally generated -80 volts into one cable. The frequency controls consist of voltage steps corresponding to the 1 MHz and 10 MHz bandswitches of the ARC-114.

The antenna will utilize the existing mounting holes for the FM30-10 antenna, with one exception. The electronically tunable antenna requires one additional hole for the power/ control connector. All other mounting holes will be located in the same places. Figure 2-7 shows the mechanical mounting interface.

A further description of the antenna's mechanical configuration is contained in Section 5.

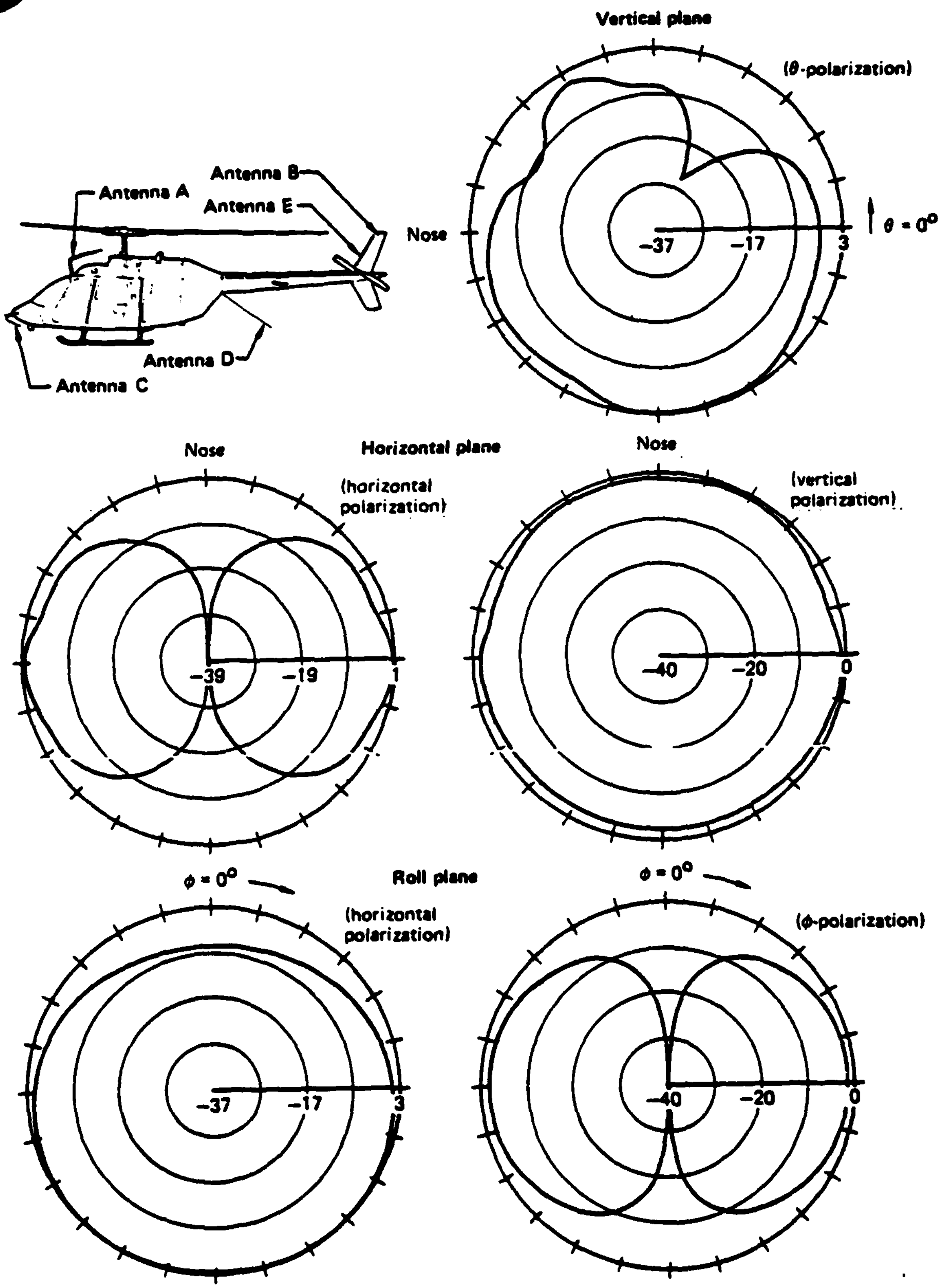

Figure 2-4. Computed Power Gain Patterns in Free Space for OH-58A at 61.65 MHz, Antenna Type D (from ref [1])

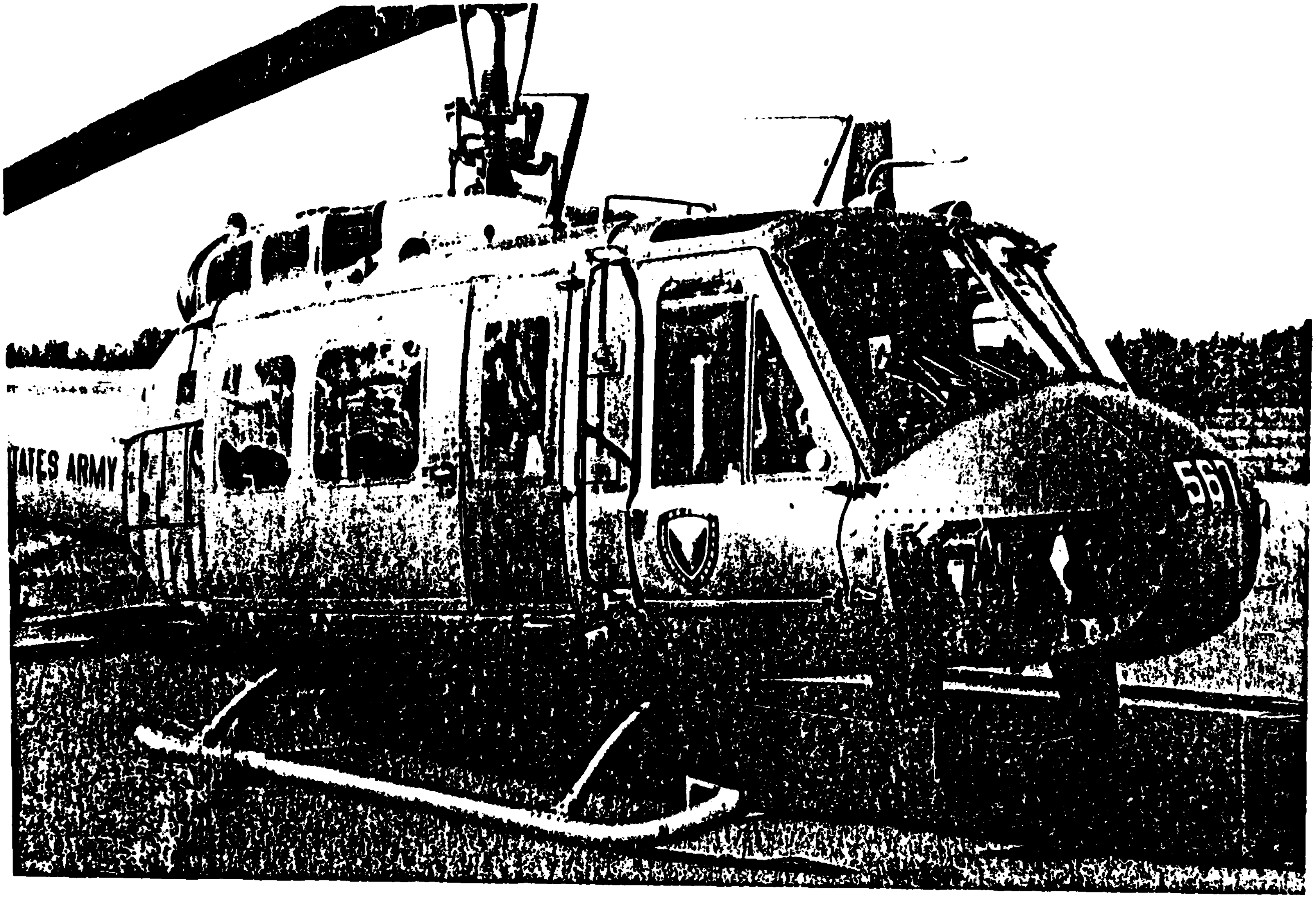

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FIGURE 2-5. PHOTO OF UH-1 SHOWING EXISTING ANTENNA LOCATION

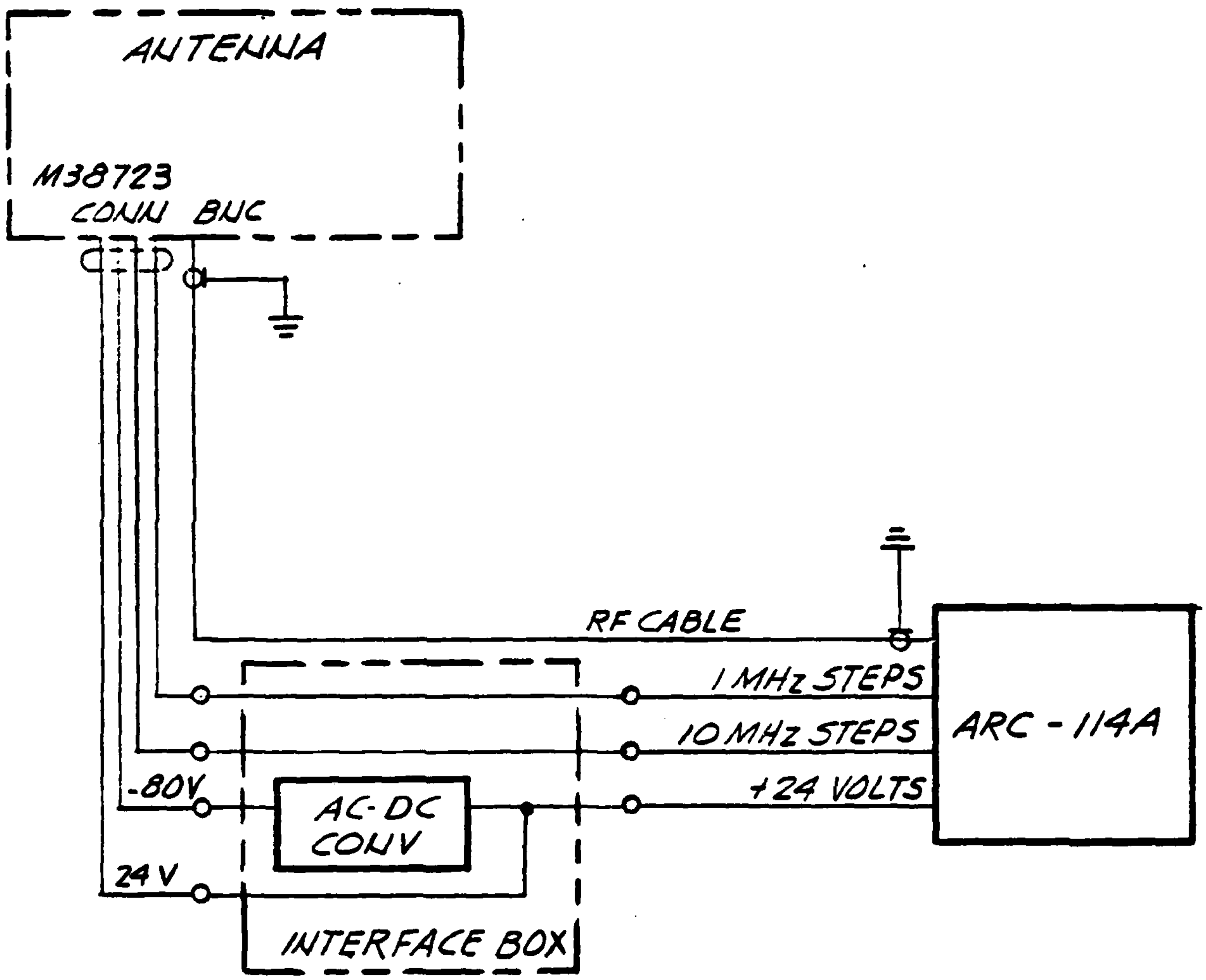


FIGURE 2-6 ANTENNA ELECTRICAL INTERFACE

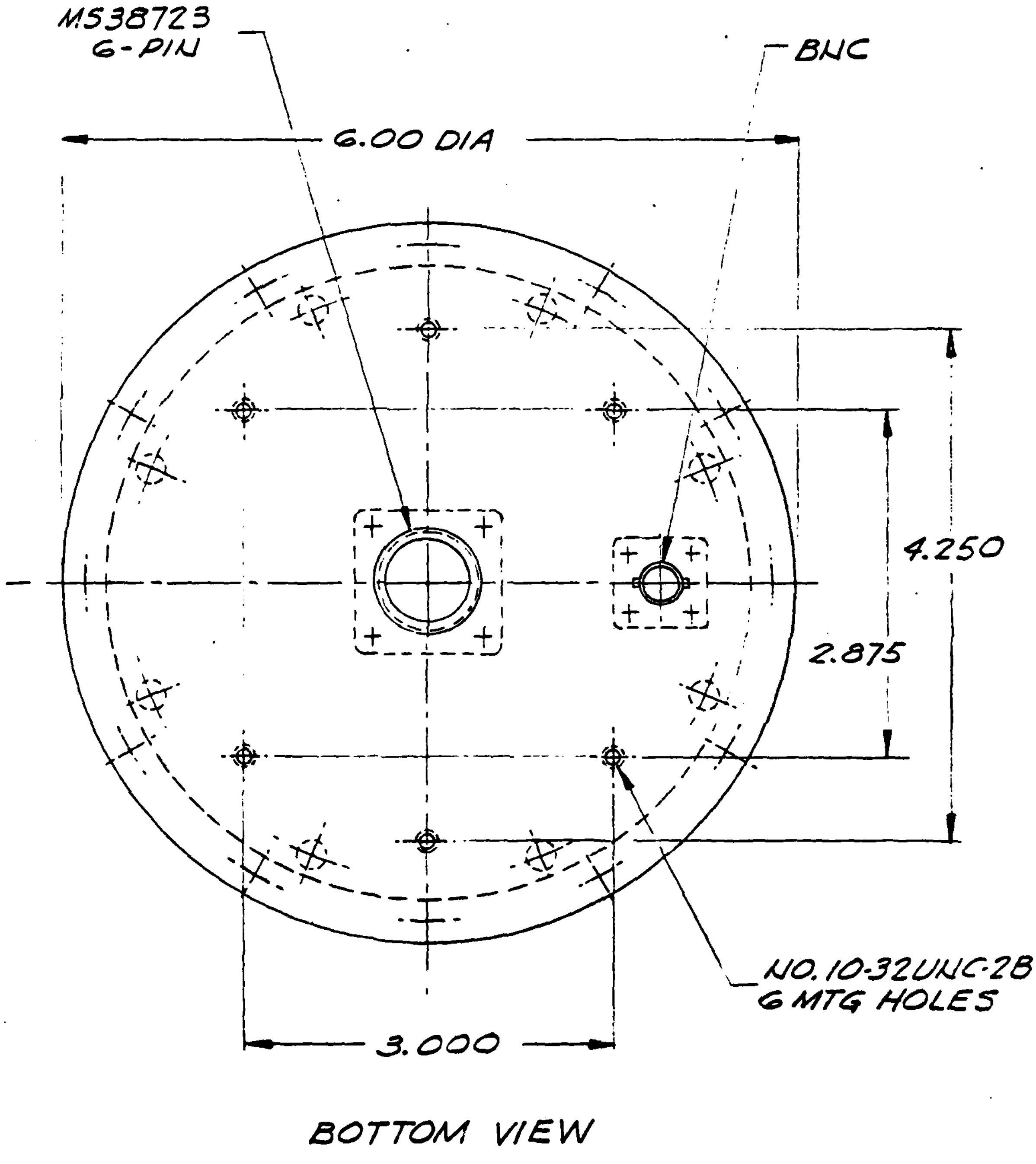


FIGURE 2-7 MECHANICAL MOUNTING INTERFACE

3.0 ELEMENT DESIGN

The element configuration has been selected to optimize the fundamental tradeoffs between size, bandwidth, and efficiency. A radiating element with maximum bandwidth for its height has been selected.

The radiating element for the vhf-fm antennas is restricted in height by several factors: clearance of the rotors, aerodynamic drag, and structural strength. All three factors make a low antenna important, although the first factor is clearly the most compelling. A height of 30 inches as a maximum has been selected, based on thr rotor clearance of approximately 40 inches, and to approximate the overall height of the bent whip, (FM 30-10-1) which is about 27 inches.

For an electrically small monopole (such as our 30 inch antenna at 30 MHz), the impedance bandwidth is proportional to the power factor. The power factor of the antenna at a given frequency is simply the radiation resistance divided by the reactance. Thus, to maximize the element bandwidth, the ratio of resistance to reactance should be maximized. Figure 3-1 shows some simple formulas derived by H.A. Wheeler for resistance and reactance of monopole elements. As expected, the fatter blade element has a wider bandwidth (greater power factor) than a thin monopole of the same height. A higher element, of course, also has a wider bandwidth. The equation shows that a 30 inch by 15 inch blade can have the same bandwidth as a 52 inch whip.

To confirm this analysis, and to evaluate the element bandwidth at higher frequencies where the formulas are not applicable, impedance measurements were made on a number of one-tenth scale elements. Figure 3-2 shows the equivalent full scale dimensions of the elements tested. All measurements were made using a Hewlett Packard HP410 network analyzer, with the reference at the base of the element.

Figure 3-3 shows the measured impedance plot of the selected element. The impedance is plotted on a Wheeler chart, similar to the Smith chart, but with open circuit and short circuit at the top and bottom, respectively. Also, note that capacitive reactance is to the left and inductive to the right. The radial distance from the chart center is reflection coefficient, the same as the Smith Chart. Several quantities are of interest: first, the resistance and reactance at 30 MHz is important. A greater power factor at 30 MHz allows the highest efficiency for a given bandwidth. Second, the first resonance (low impedance crossing of the real axis) gives a measure of the effective electrical length of the antenna. The second (high impedance) resonance is also of interest because it is more difficult to match the antenna if the second resonance falls well within the operating band.

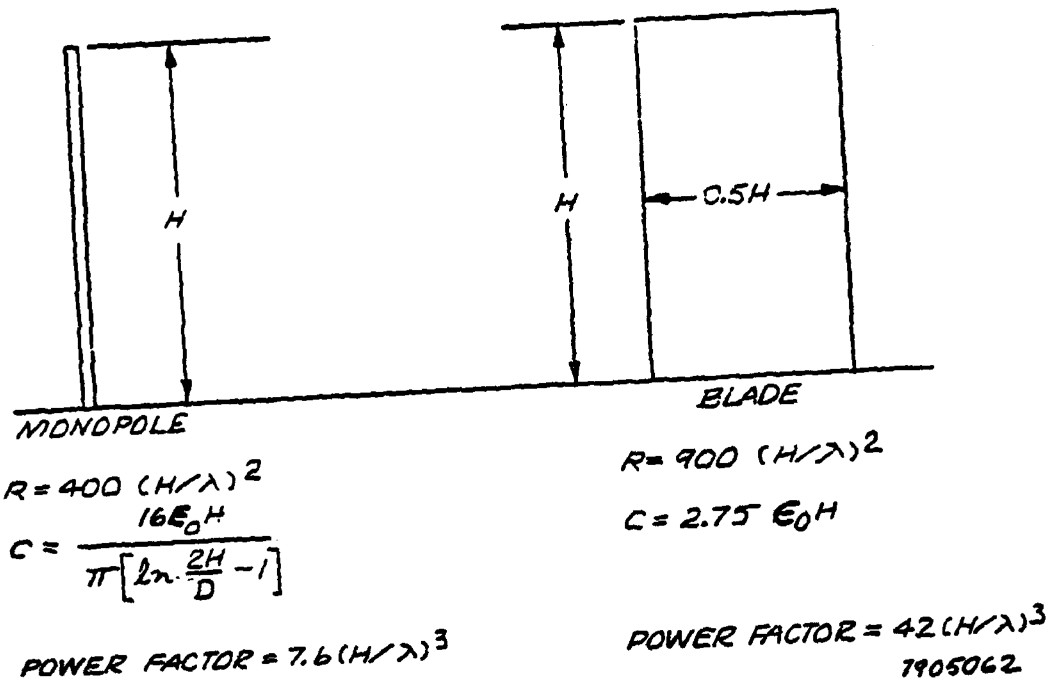


Figure 3-1 Resistance and Reactance of Monopole Elements is Calculable

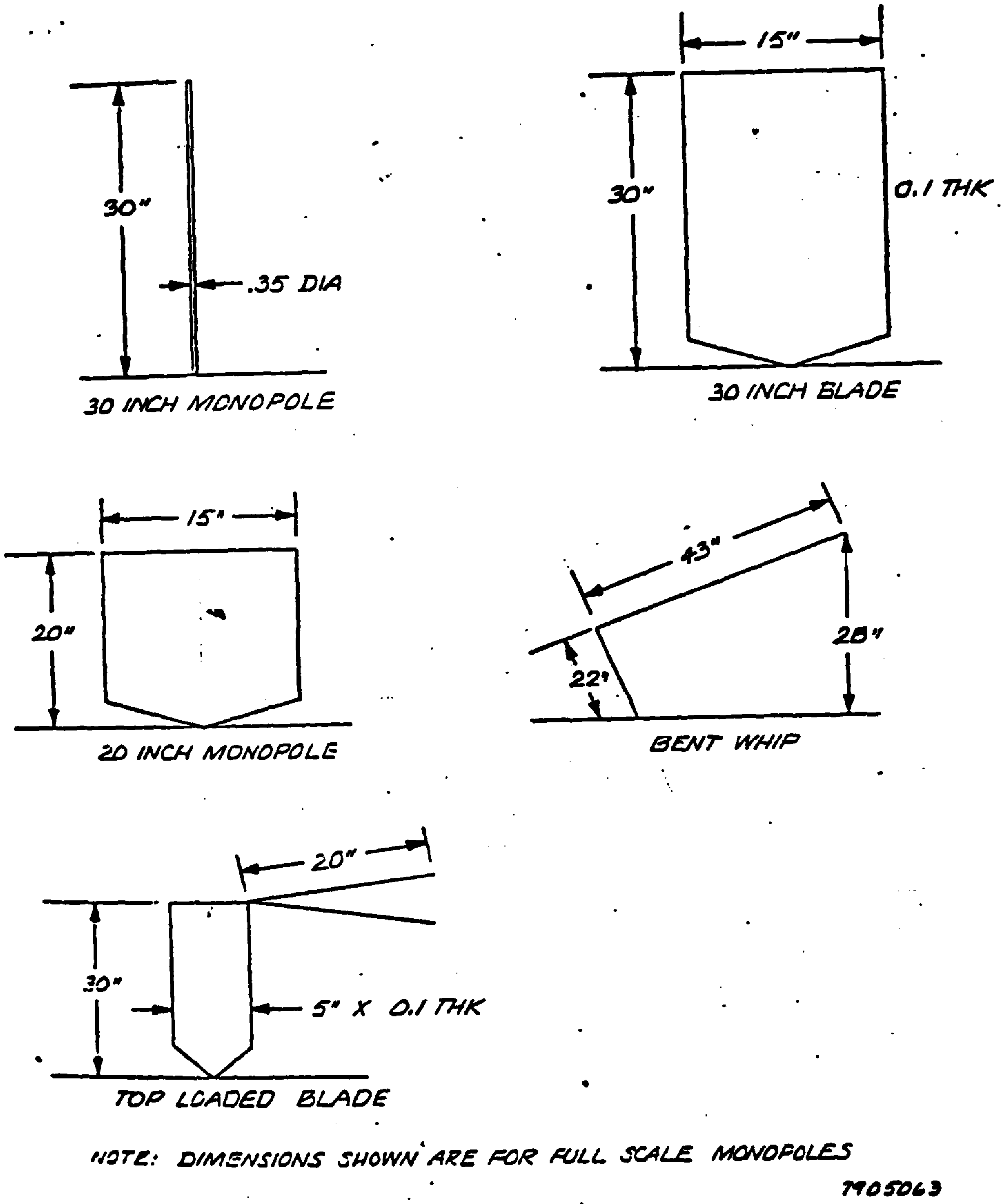


Figure 3-2. Alternative Monopole Configurations

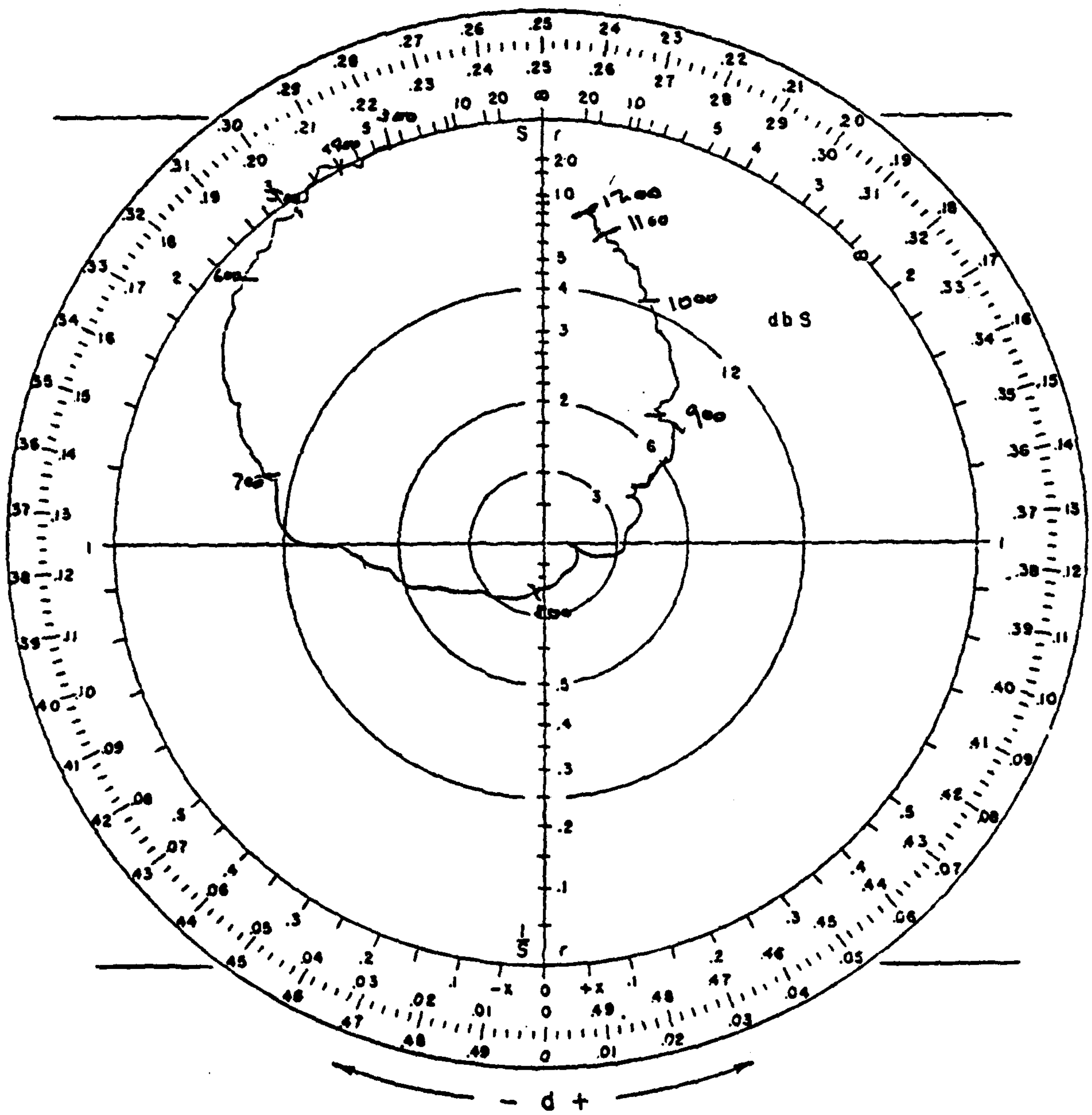


Figure 3-3 Measured Impedance of 1/10 Scale 30 Inch Monopole

The bent whip and the selected top loaded blade have equal power factors at 30 MHz. They are both better than a 30 inch blade because of the top loading of the horizontal wires, which make the current more nearly uniform along the vertical segment. The bent whip radiates well at 30 MHz because of its height (note that the vertical projection of the whip must be included, giving a total height of 28 inches) and its top loading.

A slightly better antenna element has been designed and tested. A sketch of the element is shown in Figure 3-4. This element is very similar to the radiator which was described in the proposal, but provides a slightly lower Q (higher power factor) at 30 MHz. This result is achieved by making the bottom half of the vertical radiator a thin pair of wires rather than a wide conductor. This type of construction minimizes the unwanted shunt capacitance between the element and the ground plane, thus minimizing the non-radiating stored energy which increases the Q.

A breadboard radiating element has been constructed and measured while mounted on a 12-foot diameter ground plane. The impedance is shown in Figure 3-5. Note that the impedance is very similar to that measured on the scale model.

The measurements on the breadboard antenna indicated that the impedance is influenced by the size of the ground plane. Thus the final measurements must be made on a full-scale mockup or an actual helicopter.

The diode driver consists of six integrated circuits mounted on a separate circuit board. The network includes U6, which is a high voltage driver circuit. The logic converts the voltage steps from the ARC-114 into bias for the PIN diode switches.

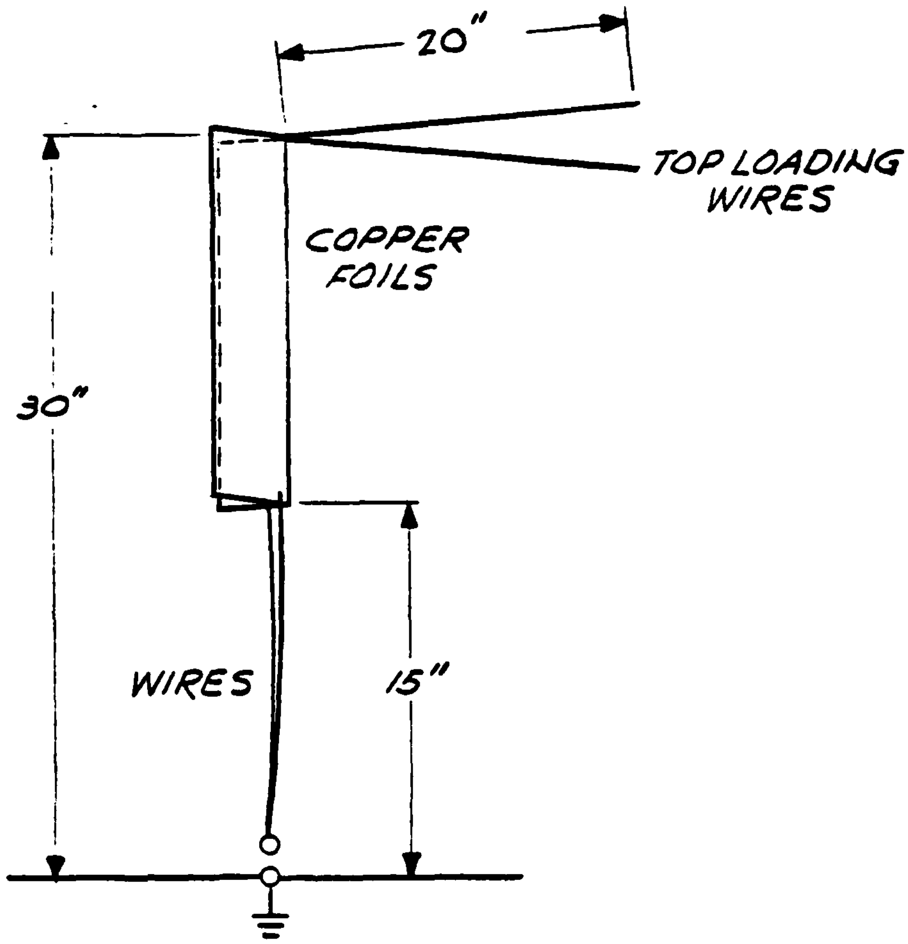


FIGURE 3-4 IMPROVED TOP LOADED BLADE

4.0 MATCHING NETWORK

The function of the antenna tuning network is to transform the radiating element impedance to a nominal resistance (usually 50 ohms) over a specified frequency band and for a given VSWR tolerance. Fundamental limitations have been defined for the match and bandwidth achievable by tuning networks. Fano for example, has calculated curves for a small antenna which can be represented by a series resonant citcuit. Figure 4-1(a) shows how the reflection of the antenna is a function of the antenna bandwidth, the operating bandwidth, the required VSWR, and the complexity of the tuning network.

As an example, consider the selected top-loaded blade. As presented in the previous section, the element itself has a power factor (ratio of radiation resistance to reactance) of 0.09 at 30 MHz. First, suppose the element is single tuned, meaning that one resonant circuit is added, as shown in Figure 4-1(b). The curves show that the element can be matched to 2:1 VSWR over a bandwidth equal to approximately 0.5 x PF; therefore, the operating bandwidth will be 0.5 x .09 x 30 or 1.35 MHz. If a double-tuned matching circuit is used (as shown in Figure 3-1(b), the bandwidth increases from 0.5 to about 1.6, corresponding to a 4.3 MHz. If an infinite number of circuits were added, the bandwidth would increase to approximately 7.8 MHz.

While these curves are useful in estimating antenna bandwidth, they must be used with care. The derivation assumes an antenna element which can be represented by a simple series resonant circuit with a resistance in series. A small element does not have a constant resistance, and at the high end of the 30-88 MHz band the element is not a simple resonant circuit. Thus, the curves can provide very accurate information only for relatively narrow bandwidths. The curves will provide accurate information for the 30 inch blade at 30 to 40 MHz.

Measured data on a scale model of the top loaded monopole was used to derive a preliminary design for the matching network. The impedance of the blade can be matched to a VSWR of 2 to 1 by using four tuning circuits. Figure 4-2 shows the calculated impedance locus for each of the four bands. Note that the bandwidth of each band increases with frequency. The lowest band is 30 to 33 MHz, while the highest band is 55 to 88 MHz.

The schematic diagram of the matching network is shown in Figure 4-3. Each of the four tuning circuits is double tuned to achieve the widest practical bandwidth for each band. Each tuning circuit is switched by two PIN diodes, one at the input and one at the output. Bias voltages for the PIN diodes are fed through the RF chokes shown in Figure 4-3. The diodes must be heat sunk to limit the temperature rise resulting from the power dissipated in the diode's internal resistance.

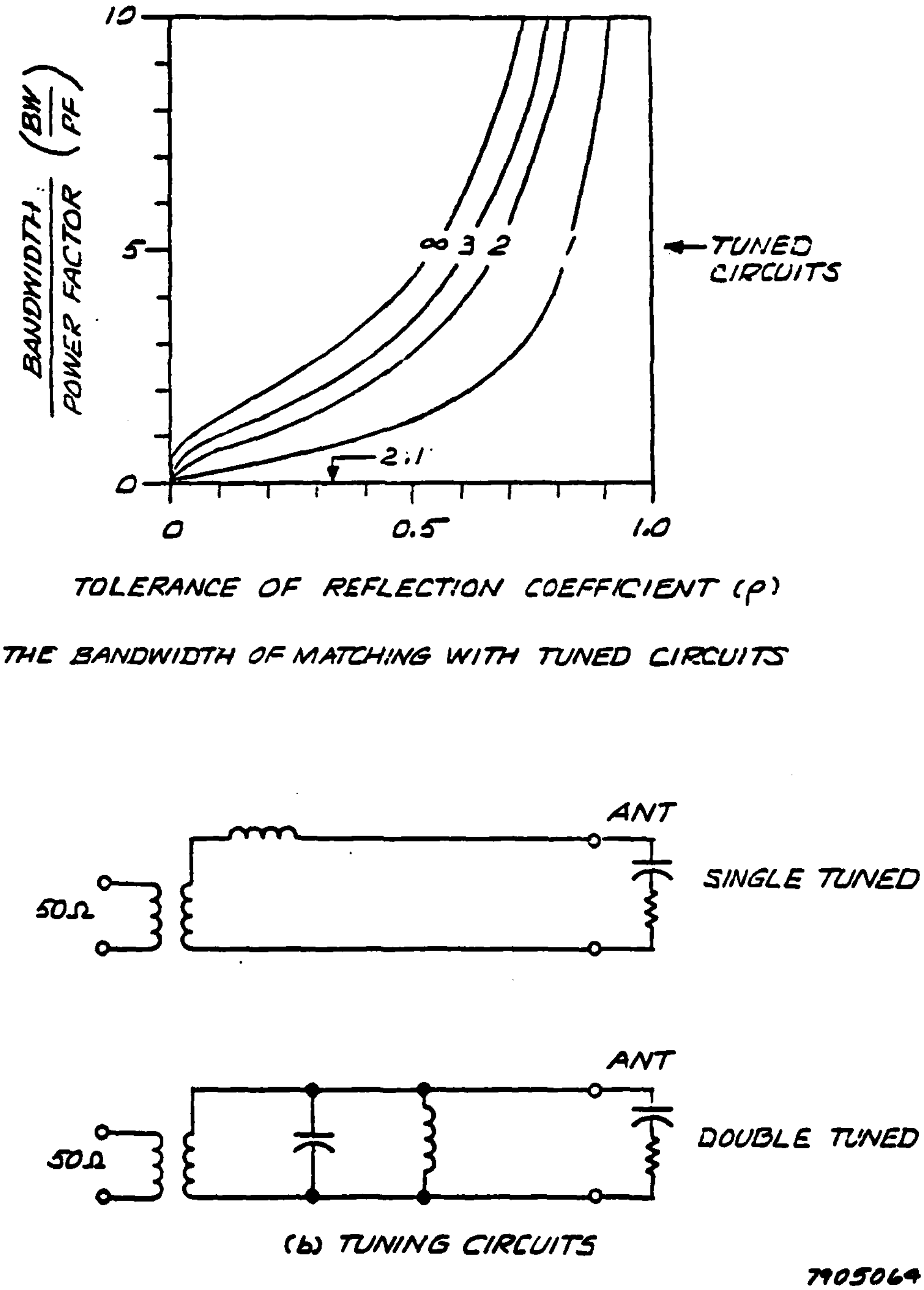
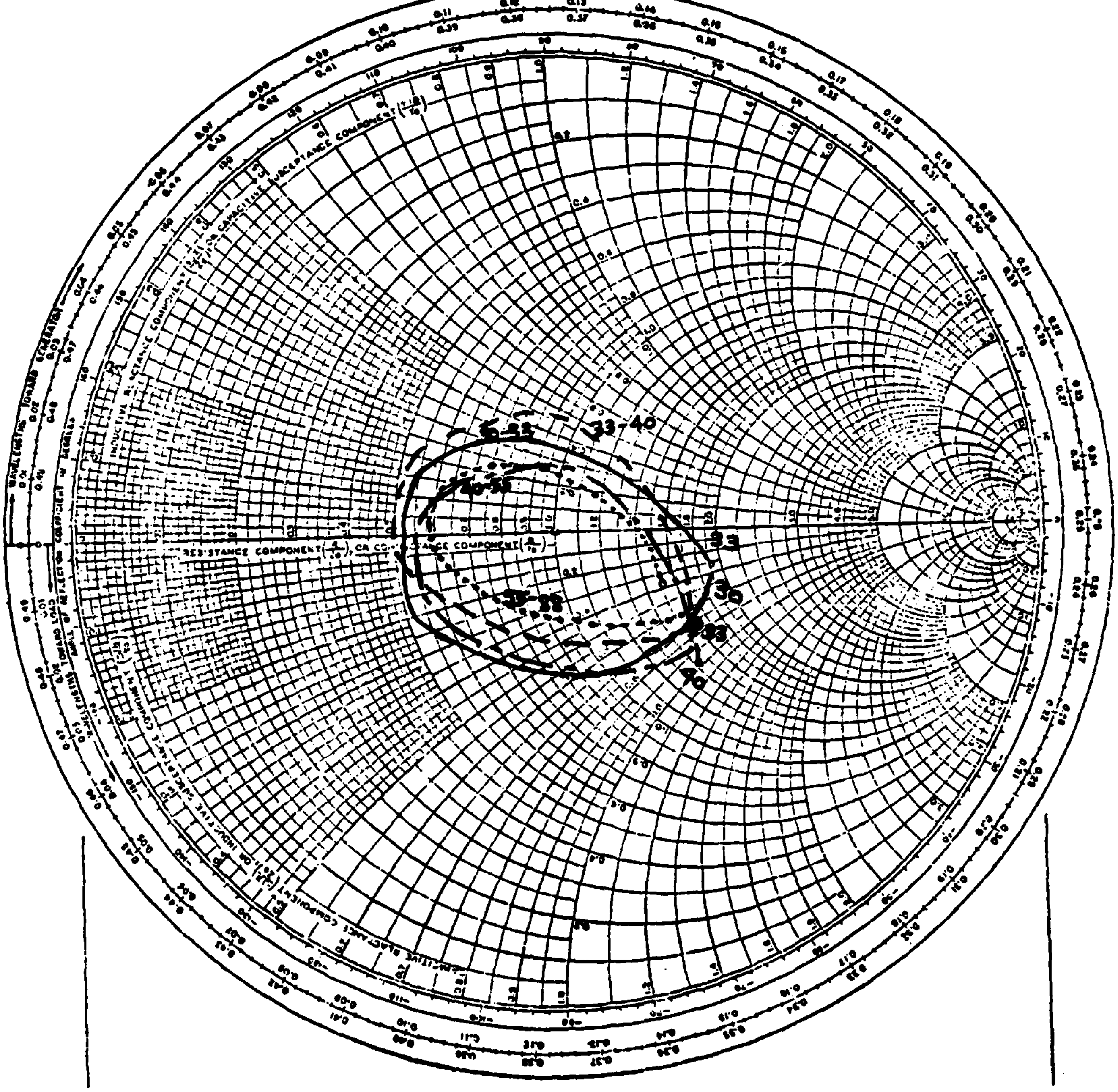


Figure 4-1. Limitations of Tuning Networks



(BASED ON MEASURED IMPEDANCE OF TOP LOADED MONOPOLE)

Figure 4-2. Calculated Impedance for Four-Band Matching Network

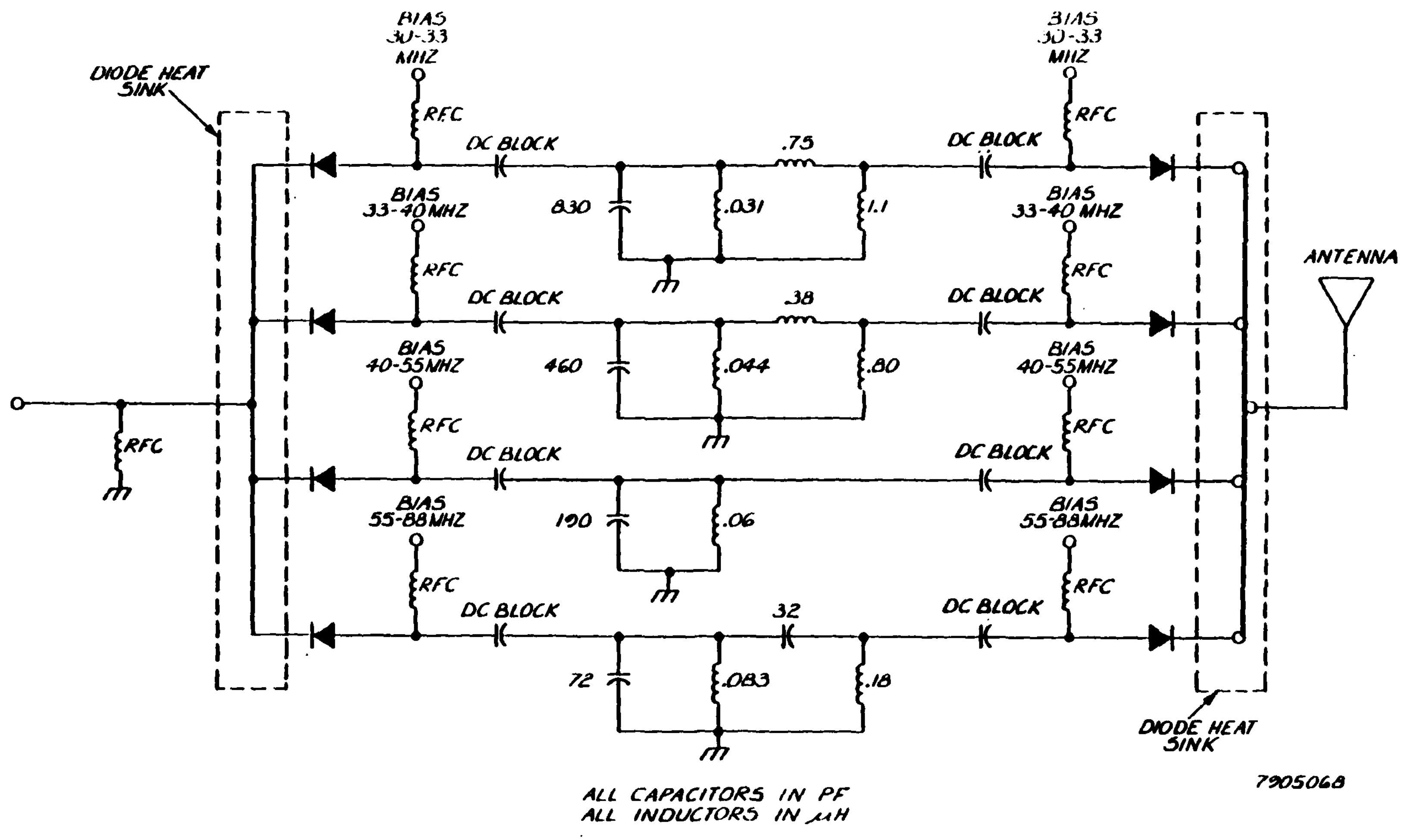


Figure 4-3 Matching Network, Schematic Diagram

Care is required to maintain a high efficiency. Note that no resistors or inefficient components are used. We have also avoided using ferrite components, which have significant losses in the VHF band. The configuration of the air wound coils have been selected for maximum Q.

Standard capacitors are available with the Q factors required. However, standard inductors do not meet these requirements. Harold A. Wheeler was consulted in the design of these elements,resulting in the choice of optimum design parameters.

One associated problem in the design of high Q coils is coupling of coils in the circuit design. This was resolved by placing the coils in cans which shielded the inductors. A typical inductor was designed, constructed and tested. The results are shown in Figure 4-4.

The measured values of shielded inductance were about 5% higher than those attained theoretically. The theoretical values were attained using an inductance chart and the physical dimensions of the measured coil. The measured Q was about 50% lower than calculated, but is still acceptable.

Special diodes have also been selected to minimize loss. The diodes are high voltage PIN types, noted for the ability to rapidly switch, yet also handle high rf power. Hazeltine has built a number of high power L-band switches using these types of diodes. Typical performance is 1 kW peak power and 1 μs switching time. Another attraction of the PIN diodes is the relatively low bias required. The diode can carry more rf voltage than the bias voltage without conducting over any part of the rf cycle. Thus, the diode will handle 1000 peak volts of rf with only 80 volts of bias. Similarly, the forward bias is only 200 mA, although the diode may handle several amperes of rf current.

Power dissipation in the forward and back-biased diodes greatly affects both the antenna efficiency, and the thermal requirements of the diode heat sink. To maximize efficiency and minimize the size of the heat sink, the following restrictions were considered when selecting pin-switching diodes:

1) Low Series forward bias resistance	Rs	$\leq$ .3 ohms
2) High Reverse Bias Resistance	Rf	$\geq$ 50K ohms
3) Low Thermal Impedance	Θ	$\leq$ 5°C/watt

The effect of the tuning circuit on antenna efficiency was calculated using typical component values and associated Q factors. The top-loaded monopole was found to have a Q of 20 at 30 MHz. Tuning components were chosen to have Q factors of 250 in this band. This value was chosen to maximize antenna efficiency and keep component values at practical sizes. Presently, there are two candidate diodes being considered.

	Q MEASURED	L uH MEASURED	Q MAX THEORETICAL	L uH THEORETICAL	% Q VARIATION	% L VARIATION
UNSHIELDED	240	.450	480	.40	50%	11%
SHIELDED SHUNT	240	.428	480	.40	50%	6%
SHIELDED SERIES	240	.423	480	.40	50%	5%

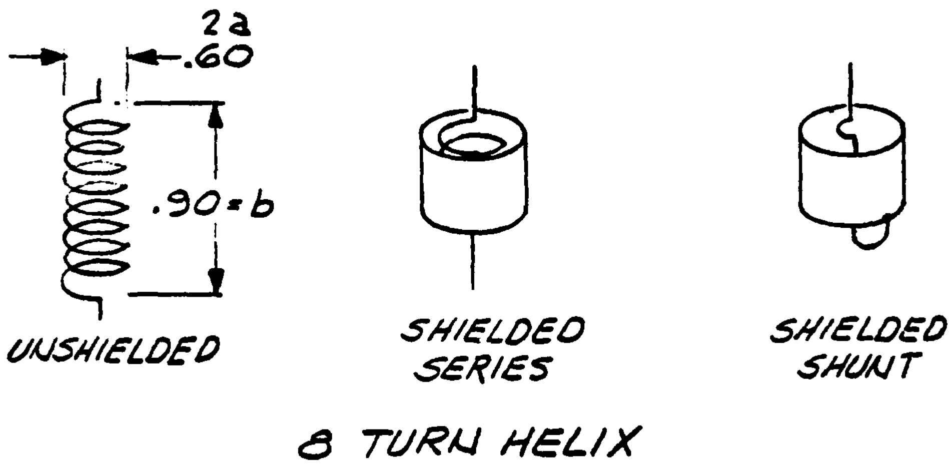


FIGURE 4-4 DESIGN OF HIGH-Q INDUCTORS

In the efficiency calculations, the characteristics of the Unitrode UM4900 PIN diode were used. Table 4-1 shows the calculated efficiency, based on realistic component values, for all four bands.

TABLE 4-1

CALCULATED ANTENNA EFFICIENCY FOR FOUR BANDS

Frequency Band (MHz)	Antenna Efficiency	Diode Power (1)	Diode Power (2)
30 - 33	79%	6	.30
33 - 40	92%	1.4	.26
40 - 55	98%	1.0	.24
55 - 88	99%	.6	.24

(1) Power dissipated in diodes at antenna

(2) Power dissipated in diodes at RF Input

The resulting efficiency corresponds to a loss of 1 dB for the 30 to 33 MHz. With a typical directivity of 2 to 3 dBi for a monopole on the helicopter, the average gain of the element will exceed the 0 dBi specification. For the higher bands, the gain will be commensurately higher.

Power Capacity

The power capacity of some existing antennas is limited by the resistive loading incorporated into their design. The resistor may have to dissipate up to 90 percent of the input power, thus a very high power resistor, say 100 to 150 watts, may be required for a 100-watt input.

The Hazeltine design approach is nominally lossless, thus the antenna can accommodate 100 watts with no dissipation problems. The total dissipation loss in the diodes and network is calculated to be 1 dB or less (10 watts out of 50), depending on frequency. The average power capacity is limited by the size of the heat sink and the thermal resistance of the diodes. Diodes with a thermal resistance of 2 to 4°C/watt are being evaluated.

In the low frequency band the 4 parallel diodes in series with the antenna dissipate a total power of 6 watts. This is the worst case power dissipation.

A heat sink is required to provide a low thermal resistance between the diode and the environment. Calculations have shown that an unacceptably large heat sink is required if it is enclosed completely within the fiberglass radome. In order to keep the antenna weight at a minimum, a light aluminum heat sink is connected to a heat radiator band located on the exterior of the blade. Thus the heat is radiated directly to the exterior environment. A thermal analysis has shown that the diode temperatures will remain within acceptable limits when the antenna is subject to 60 watts continuous input at 71 degrees C.

The peak power capacity of the antenna is limited by the breakdown voltage of the diodes used in the switched tuning network. The peak input power, 110 watts, corresponds to 74 volts instantaneous rms across 50 ohms. However, the diode at the output of the tuning network will see a substantially higher voltage because of the high Q of the radiating element at 30 MHz. Based on measured impedance data, the instantaneous rms voltage will be 400 volts, or a peak voltage of 616 volts. PIN diodes have been selected with a 1000-volt breakdown voltage, thus affording a 2-to-1 safety factor. The peak circuit voltage of 600 volts does not represent a problem for components or layout. The dielectric strength of air is approximately 150 volts per mil, so that a spacing of .01 inch affords an ample safety margin. The rf voltage will be significantly less at frequencies above 40 MHz because the Q is less.

In summary, all components have been selected to minimize loss. We expect, based on these preliminary calculations, to achieve a loss of 1 dB or less in the network. This will result in a gain of 1 to 2 dBi, depending on the pattern of the radiating element when located on the helicopter. Because the matching networks are individually designed for each band, the efficiency can be optimized for each band. The most difficult band has been the one treated in the calculations - the 30 to 33 MHz band.

The diode switching speed is largely dependent on the diode biasing and driver circuit. A sophisticated high speed driver is required to achieve 1 microsecond switching times, and is unnecessary for this application. Figure 4-5 shows the proposal control logic and diode driver. The circuit requires a total of only six chips, one of which is the high voltage driver. The logic configuration is designed to interface with the ARC-114 transmitter. According to the operation and maintenance manual, 1 megahertz as well as 10 megahertz voltage steps are available.

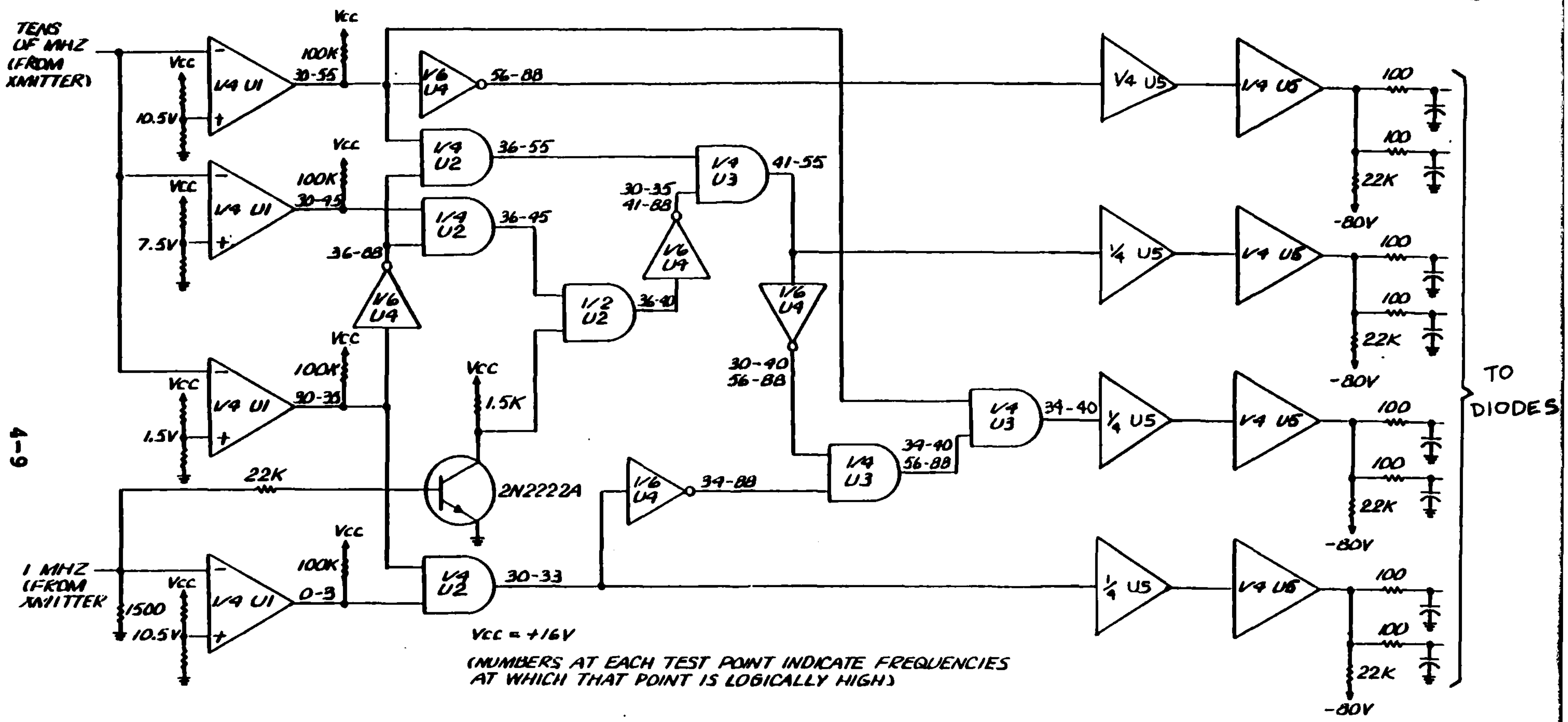


Figure 4-5. DIODE DRIVER LOGIC, CIRCUIT BLOCK DIAGRAM

The circuit must be provided with -80 vdc. Hazeltine will provide a DC to DC converter as part of the interface box.

A similar driver circuit has already been developed at Hazeltine for an Army application. We have developed a 30-88 MHz switched meander delay line for a broad band antenna array. The present configuration uses diodes rated to handle 25 watts of input power. Care was taken in the design in order that significant harmonic output was not generated by the "off" switch sections -- in this instance harmonic output is in the neighborhood of 60 dB down. An analysis of intermodulation for the present diodes indicates that the harmonics of the fundamental should be greater than 80 dB down.

5.0 MECHANICAL DESIGN

The antenna will be mechanically designed for light weight, low drag, and structural strength.

The antenna is shown in a cutaway view in Figure 5-1. The aerodynamic configuration of the upright portion provides very low drag at helicopter speeds. The airfoil shape is formed from two fiberglass halves, which are then bonded together.

The fiberglass halves contain two copper radiating elements bonded inside the fiberglass. These copper foil elements are connected to the two twenty-inch top loading elements. The top loading elements consist of wires located within .375 inch diameter fiberglass tubes which are bonded to the streamlined fiberglass shells. The copper foils are in turn connected to a pair of vertical wires which terminate in a banana jack bonded to the fiberglass shell. The fiberglass shell, once assembled, is filled with a lightweight polyurethane foam to add rigidity and damp vibration.

All the electronic tuning components are located in the base of the antenna, as shown.

When the antenna is dismounted from the aircraft the electronics module may be removed by unfastening several screws and pulling the module, including the baseplate and connectors, out of the blade. The only required connections between the electronics module and the blade are the banana plug and the screws which connect the diode heat sinks to the heat radiator bands. Thus a damaged blade may be discarded without discarding the more costly electronics. Also, a defective electronics module may be removed and replaced in the field, with the defective module returned to depot level maintenance.

The electronic module consists of two printed circuit boards, two heat sinks and two connectors.

The topmost heat sink contains four PIN diodes, and is connected directly to the radiator via a banana plug located on top of the heat sink. The heat sink is connected to an exterior metal heat radiator band. The band is located in such a manner as to minimize the shunt capacitance between the band and RF ground.

The four diodes are connected to the RF circuit board. This board contains all of the matching network components, as well as the RF decoupling networks for the PIN diodes.

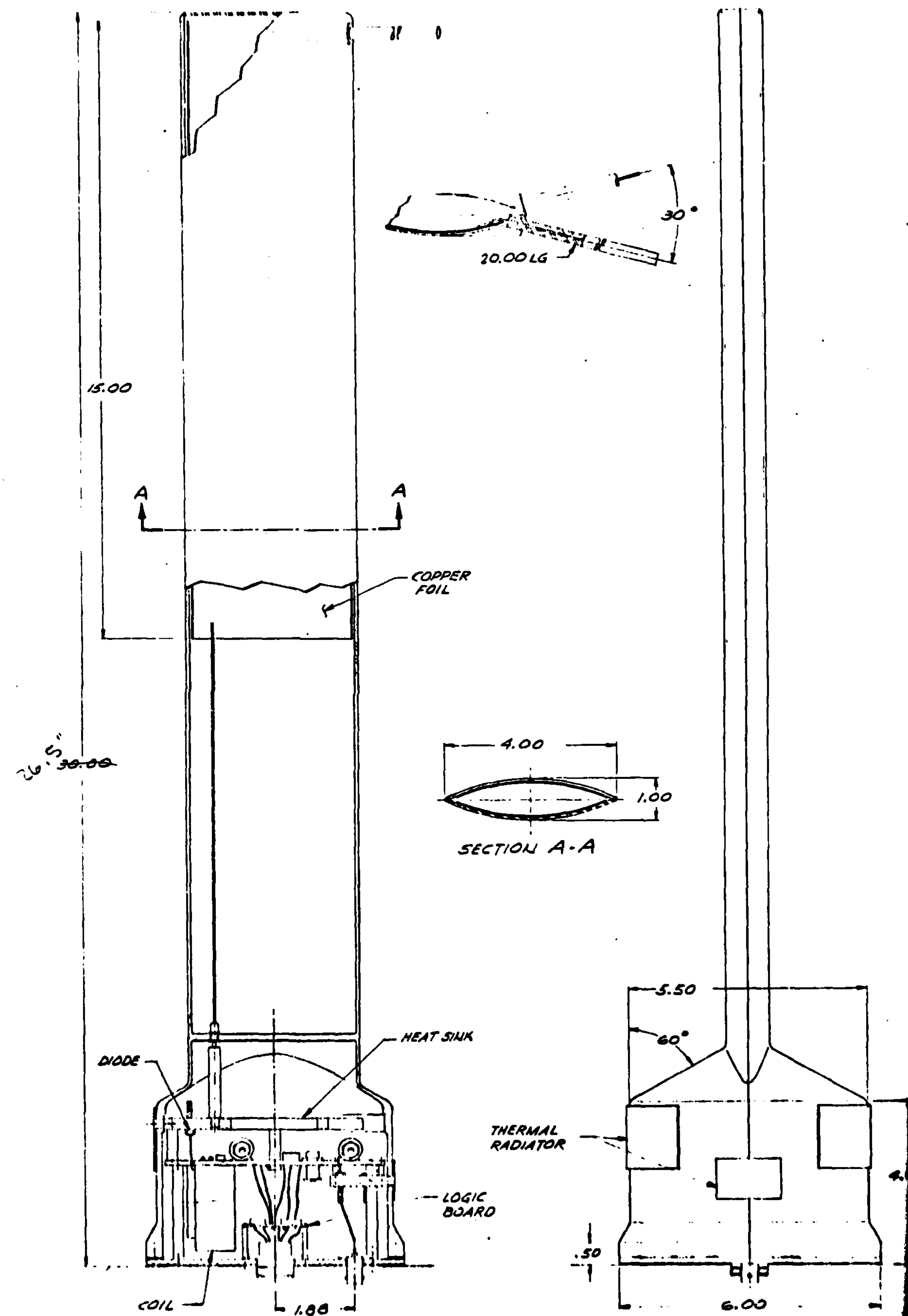


FIGURE 5-1. CUTAWAY VIEW OF ANTENNA BLADE

The four diodes located on the input side of the matching network are mounted on a small heat sink located below the RF board. This heat sink also is connected to a small external heat radiator band. The output heat sink is also connected to the input RF connector.

The logic circuits are mounted on a small board positioned below the RF board. The logic board's diode driver is wired to the bias circuits of all the diodes.

The circuit boards are wired directly to the six-pin power connector which is mounted on the aluminum baseplate. The circuit boards will be cushioned using a low density foam to minimize stress due to mechanical vibration.

The estimated weight of the antenna is detailed as follows:

Fiberglass (blade & tubes)	26 oz
Foam ($4/lb/ft^3$)	3 oz
Radiating Element	5 oz
Base and connectors	10 oz
Matching network	8 oz
Driver Board	6 oz
Heat Sinks	15 oz
Total	73 oz (4.6 lbs)

The antenna will be mounted using self contained threaded inserts. The same inserts locations as the FM 10-30-1 will be provided.

The materials and finish of the blade will be consistent with the requirements of MIL-E-5400R, and MIL-STD-810C. The exterior of the antenna will be finished with a black rain - erosion-resistant coating.

The antenna will be analyzed to establish that the design satisfies the requirements for vibration, shock, balance and drag. Because the radiator is located in the same position as the existing bent whip, there should be no significant impact on aircraft performance, pilot visibility, entrance or egress.

The weight and balance of the antenna element can be readily calculated and measured. The drag can be analyzed assuming laminar air flow and a drag coefficient defined for the fineness of the blade shape. The stress imposed on the blade will be calculated.

Compliance with shock and vibration requirements is required to assure that the antenna is structurally sound during flight, and in the event of a crash. The antenna is structurally examined for loading in three mutually perpendicular directions. The most critical mode, or weakest design feature, will be identified and analyzed.

Shock

The maximum shock load, based on crash safety, is 30 g. The shock pulse is a half-sine wave of 11 milliseconds duration, corresponding to a pulse frequency of 45 cps. The shock may be amplified by the antenna structure if the resonant frequency lies between 45 and 90 Hz. The amplification factor is illustrated in figure 5-2 for single degree of freedom system. Because the amplification factor could be as high as 1.7, the antenna structure will be designed to accommodate the amplified acceleration without exceeding the ultimate strength.

Vibration

The antenna prototype will be tested to a 5 g input vibration level. Operational vibration levels should be lower. Mechanical resonance will be analyzed. Because the antenna is built of epoxy fiberglass, it will have high damping and thus will have an amplification of less than 10. Thus, the vibration will result in effective accelerations of less than 50 g.

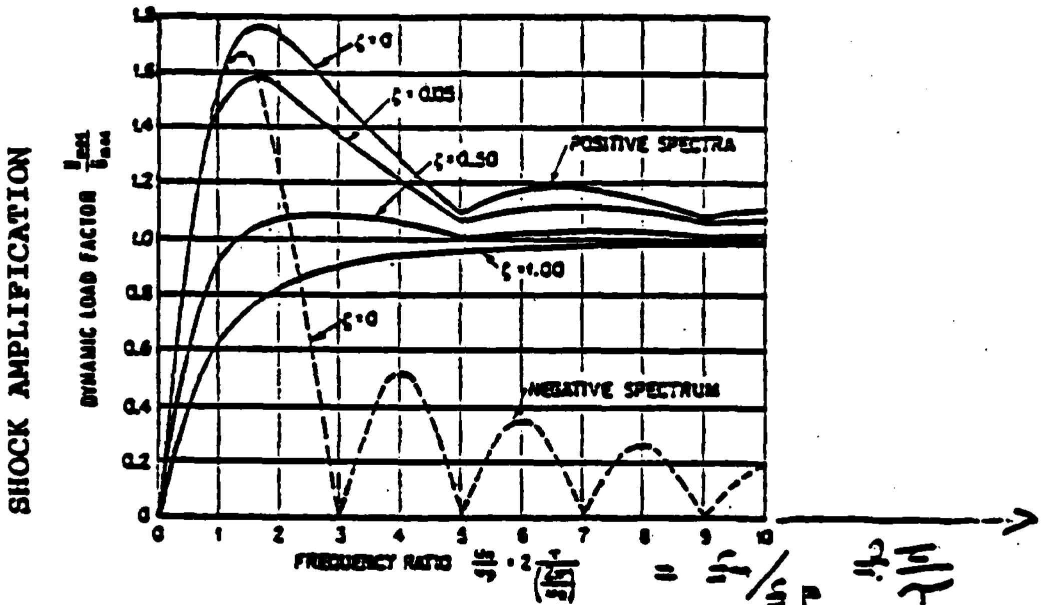


FIG. 42.12. Maximum positive and negative response factors (dynamic load factor) for half-sinusoidal pulse of acceleration. The fraction of critical damping in the system is indicated by ζ. (After R. D. Mindlin.)

Figure 5-2. Amplification Factor

6.0 PROGRAM PLAN AND ORGANIZATION

The program organization has been revised slightly from that in the proposal. The changes, shown in Figure 6-1, provide a more efficient allocation of personnel, and change the program management function from a direct charging to indirect charging position. The design engineers have also been identified.

A program schedule, broken down by phase and by task, is shown in Figure 6-2. Because none of the tasks represent significant technical risks, the effort will be concentrated on refining the design of each subassembly for best performance.

During phase one, the design will proceed from fundamental analysis through breadboarding, and then through the fabrication of a complete antenna prototype. The individual tasks are discussed below:

1. The location of the antenna on the helicopter will be selected based on published pattern data, analysis, and on the practicality of installation.

2. The element design will be refined to achieve the widest possible bandwidth with the most attractive physical form factor. While the baseline radiator performs well, it may be possible to achieve a further improvement in the bandwidth. The variation of element impedance resulting from mounting on the airframe will also be investigated using a full scale mockup of a part of the OH-58A.

3. The matching network will be designed based on the measured impedance data from the final breadboard radiator. The key part of this task is the design of the individual components for maximum Q and minimum size. Packaging requirements and production cost will also be considered in selecting the final design. Integration of the diode switch with the network will also be accomplished.

4. The diode driver is a straightforward design effort. The circuit will be breadboarded and tested with the diodes. A final prototype circuit board will then be built up.

5. A prototype of the complete antenna will then be built and tested. The prototype will include the final radiator configuration, matching network and driver board. A sample of the fiberglass housing will be procured and the entire antenna assembled. The assembly will then be electrically and mechanically tested, including

limited temperature and vibration testing. The assembly of a complete unit assures that all subassemblies operate satisfactorily together and that the unit is structurally sound.

After the authorization to proceed, we will fabricate five deliverable models. Because these models will be essentially identical to the prototype, there is no risk of unsatisfactory performance.

The units will be tested in accordance with the approved test plan, at Hazeltine's Smithtown antenna test facility.

Data will be supplied according to the schedule shown in the program plan and in the applicable DD-1423's.

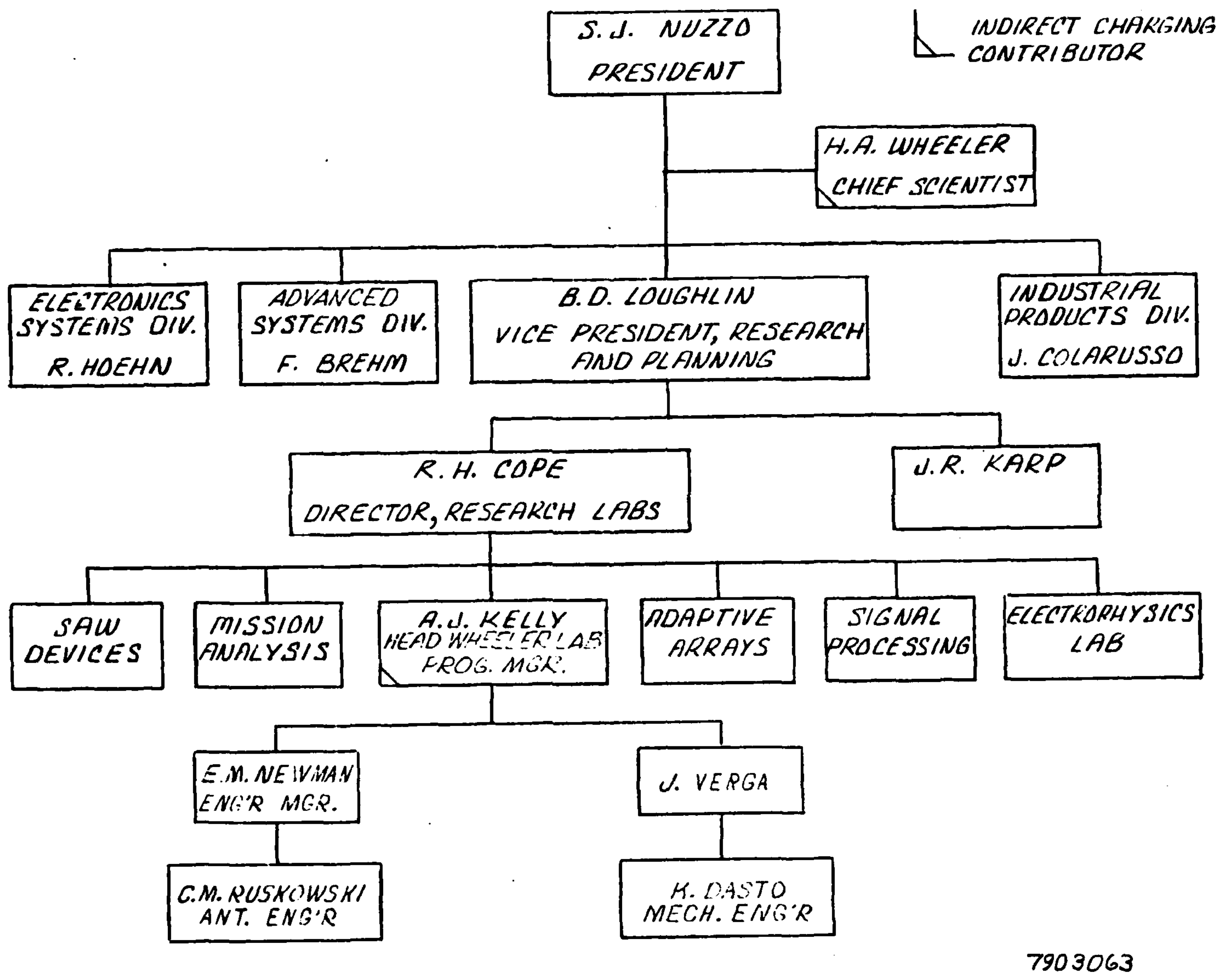


FIGURE 6-1. PROGRAM ORGANIZATION

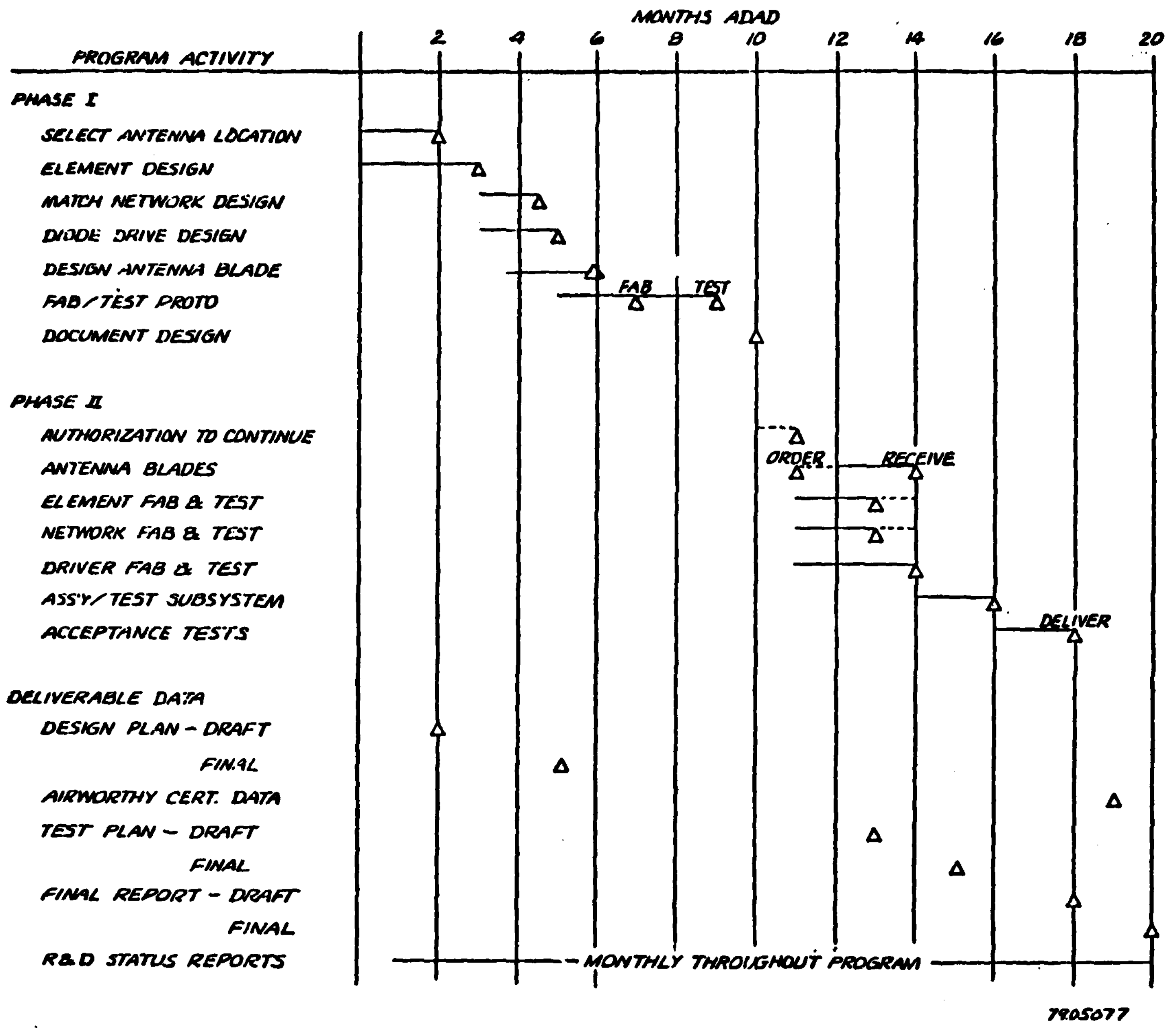
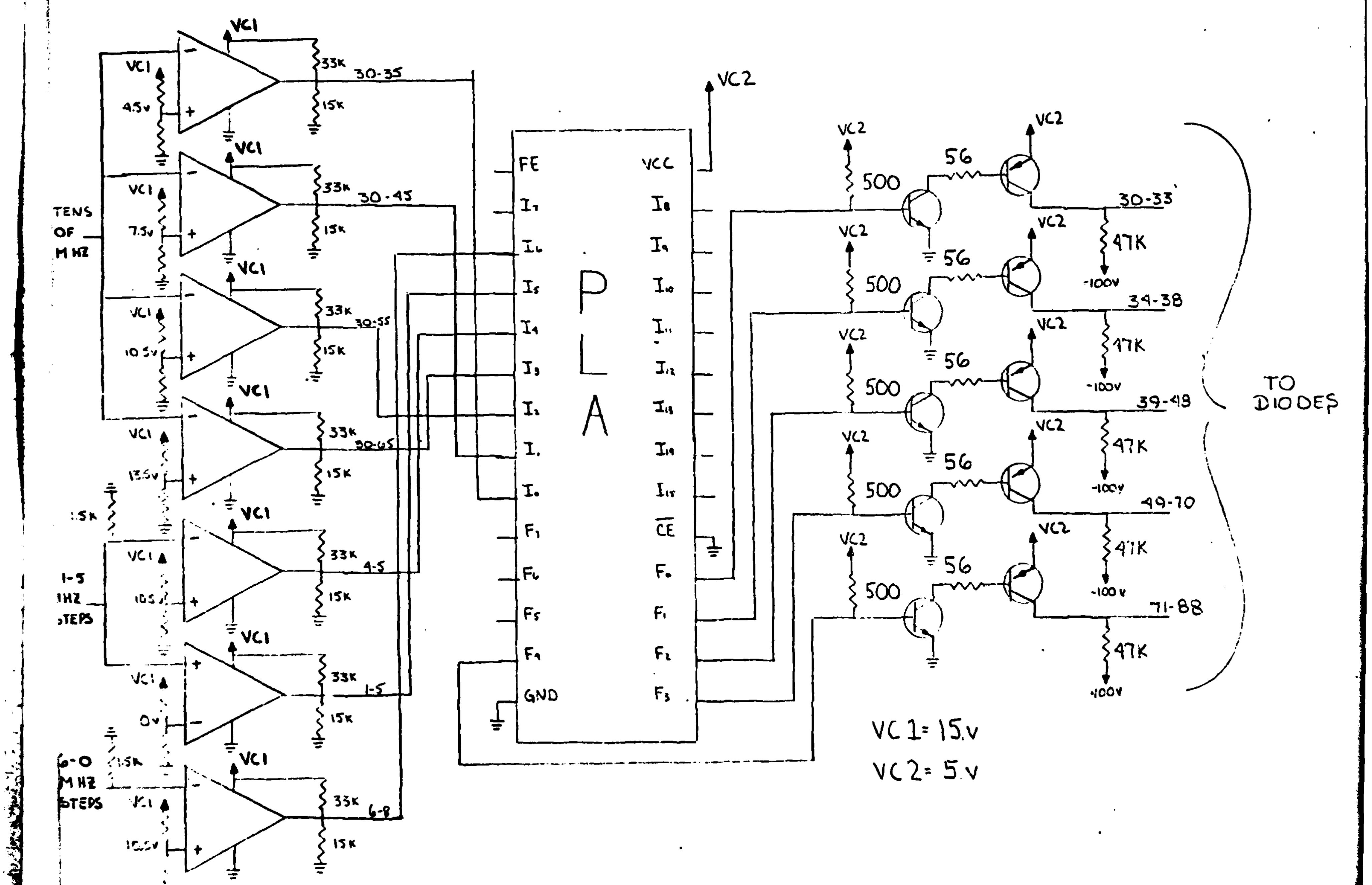


Figure 6-2. Program Schedule, Task Chart



TENS OF MHZ
1-5 MHZ STEPS
6-0 MHZ STEPS
VC1
4.5v
7.5v
10.5v
13.5v
0v
1.5K
33K
15K
30-35
30-45
30-55
30-65
4-5
1-5
6-8
VC2
FE
VCC
PLA
CE
GND
500
56
47K
-100V
30-33
34-38
39-48
49-70
71-88
TO DIODES
VC1 = 15 v
VC2 = 5 v

END

DATE
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